Eaters In The Dark:
The Primacy of Cognitive Factors For Food Consumption And Satiety

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Abstract

To compare the importance of cognitive factors relative to physiological factors for estimating food consumption and satiety, we served 64 participants lunch in a "dark" restaurant where they ate a regular two-course meal in complete darkness. Half the participants unknowingly received considerably larger portion sizes which subsequently led to higher food intake. Despite this difference, participants' appetite for dessert and their subjective hunger after the meal was largely unaffected by the amount of food they had consumed in the dark. In comparison, 32 participants in a control group who ate the same meal in the light consumed comparatively less food from the large portion and still compensated for the larger portion size by eating less dessert afterwards. Together, these results indicate that internal physiological cues do not provide accurate feedback and that visual cues are the main source of information for estimating food intake and satiety.

Nikola Tesla, the eccentric inventor, worried about eating anything which he could not visually judge the size of before he consumed it (Hunt & Draper, 1964). As Tesla was also concerned about his weight, his peculiar behavior could have been connected to a fear of overeating when lacking appropriate visual input. How important are visual cues for controlling our food consumption and when to stop eating once we start?

Physiological research has identified a number of post-ingestive satiety processes involving the integration of numerous internal signals that trigger the inhibition of our appetite (Schwartz et al., 2000; Barsh, Farooqui, & Rahilly, 2000). But this need to inhibit appetitive behavior internally would rarely come up in an environment where food resources are scarce, as the possible amount of food available to consume is externally constrained. Thus our proprioceptive signaling systems that evolved for meal termination in challenging Pleistocene environments might be less sophisticated than the signals that arose to first motivate us to eat. As perhaps felt by Tesla, this poses a problem in a world where large amounts of high-calorie foods are ubiquitous, as in our modern affluent societies; and it might even be a reason for the growing rate of overweight in numerous countries, a development sometimes referred to as the 'obesity epidemic' (Bolles, 1965; Jeffery et al. 2007; Blundell et al, 2005).

To determine how much food they have consumed and when to stop eating, people often rely instead on external cues in their environment (Fedoroff, Polivy, & Herman, 1997; Schachter, 1968). The simplest case is that people typically stop eating once they empty their plate, which can lead to increased consumption with larger dish and portion sizes (Wansink, Painter, & North, 2006; Diliberti, Bordi, Conklin, Roe, & Rolls, 2004; Levitsky & Youn, 2004; Fisher, Rolls, Birch, 2003; Rolls, Roe, Kral, Meengs, Wall, 2004). When eating in a group, people also adjust their consumption to how others at the table eat, presumably because this sets an implicit consumption norm (Herman, Roth, & Polivy, 2003).

To the extent that food intake is controlled by cognitive processes that rely on external cues, subjective feelings of satiety may depend little on the actual amount of food in the stomachs. In line with this, Rolls, Morris, and Roe (2002) found that larger portion sizes led to more consumption among participants but did not affect their subsequent ratings of hunger and fullness. Likewise, Wansink, Painter, and North (2006) showed that manipulating visual cues of how much is eaten influences further intake, suggesting that "people use their eyes to count calories and not their stomachs" (p.98). They served participants soup in a bowl that secretly re-filled through a hidden tube in the bottom. Participants who ate from these "bottomless" bowls on average consumed 73% more calories than a control group eating from regular bowls, yet they did not report having consumed more, nor were they more sated. Longitudinal studies show that such overconsumption of food is often not fully compensated by subsequent reduction of food intake, resulting in a net gain of body weight (Jeffery et al., 2007).

However, it could be that internal satiety cues do work well, but are just most often being overridden or superseded by external visual cues, and take over to guide behavior only in extreme situations. If so, people could be advised to listen to their stomachs rather than looking at their environment in order to determine when to stop eating. But would this work? How sensitive and reliable are the cues transmitted through the brain-gut axis (Herman, 2005) about how satiated we really are?

To find out, we need to experimentally control the competing external visual cues of how much oneself and others are eating. One way to do this is by serving food in complete darkness. While the amount of food provided on the plate can still be estimated by touch or by counting bites, normal-sighted people should be unaccustomed to these methods. As a consequence, the external cues become less useable and internal satiety cues can gain in importance. The reliability of these internal cues will then influence how well people eating in the dark can estimate the amount of food they consume as compared to people eating under normal light conditions. Stated differently, contrasting the behavior of people eating in the dark versus the light allows us to estimate the importance of internal versus external cues for judging satiety and consumption quantity.

Method

Overview

We experimentally tested the relative importance and reliability of internal and external satiety and consumption cues by inviting participants for lunch in a so-called "dark" restaurant in downtown Berlin, Germany. This restaurant consisted of two parts, an entrance and bar area in the light and a dining area in the back where no light was visible and patrons were served in complete darkness by blind waiters and waitresses. In the experimental condition, 64 participants were given two main courses in the dark, prepared by the restaurant kitchen, and a subsequent dessert in the light where participants could serve themselves. The amount of food served in the dark was manipulated such that participants received portions that considerably varied in size. The main dependent variables were participants' satiety after the meal and how accurately they estimated the amount of food they had consumed. Our behavioral measure of satiety was the amount of dessert that participants served themselves, assuming higher satiation corresponded to less consumption. We also gave participants a questionnaire at the end of the experiment asking them to estimate the amount of food they had consumed and how satiated they felt. In the control condition, a separate group of 32 people ate the same meal at the same restaurant but in the light.

Procedure

The experimental condition was run on two consecutive days with groups of 32 participants per day. The control condition took place several weeks later, on one day. Participants in both conditions were welcomed in the entrance area of the restaurant at around noon. Only vague information was given about the content of the food and nothing was mentioned about the size of the portions. Participants were asked to talk about anything over lunch except the food itself, and then were guided to their tables by the restaurant staff. In the dark condition, the tables were in the lightless dining room. In the light control condition, the tables were set up in the entrance area of the restaurant. Tables were shared by 8 participants. The first main course was vegetable risotto, followed by the second main course of goulash with noodles. Together with these two courses participants were served a plate with 5 pieces of white bread and a glass of plain water (refilled upon request). To measure the exact amount of food that was served to and consumed by each participant, we weighed each plate before it left the kitchen and after it was cleared from the table. Eating in the dark took about 45-60 minutes, while in the light it lasted about 30-40 minutes.

In both conditions, the dessert was served in the entrance area of the restaurant in the light. Dessert consisted of large plates with fruit pieces (tangerine, apple, and grape with cheese) impaled on colored toothpicks, from which participants could serve themselves. Each participant had a plate to drop their empty toothpicks on, so that we could assess the individual amount of dessert consumption by counting the number of toothpicks on each plate. Following this dessert, participants received a questionnaire and were then debriefed, compensated with a 10 EUR show-up fee, and dismissed.

Experimental manipulation

In the experimental condition, half of the participants on each table received small portion sizes with an average amount of 172 grams of risotto (SD = 18 grams) and 309 grams of goulash (SD = 38g) – the small-portion group. The large-portion group on the first day received approximately twice as much risotto (M = 338g, SD = 17g) while the second main course dish was kept the same size (M = 305g, SD = 31g). To test if the distribution of portion sizes between the first and the second dish makes a difference, on the second day the large-portion group instead received on average 270g risotto (SD = 27g) and 494g goulash (SD = 56g). Yet subsequent analyses revealed no consistent differences between the two days. Also, the plates were filled by the kitchen chef who eyeballed the portions, inducing some variance in the portion size. Therefore, our subsequent analyses are based on the total amount of food served and consumed, summing across both main courses on both days separately for the small-portion and large-portion groups. On average, participants in the large-portion group in the dark received 706g (SD = 77g), 225g (47%) more food than those in the small group (M=481g, SD = 42g). In the control condition in the light, the average serving sizes were 451g (SD = 69g) in the small group and 636g (SD = 75g) in the large condition. The resulting difference of 186 g (29%) is smaller than in the dark—see Figure 1.

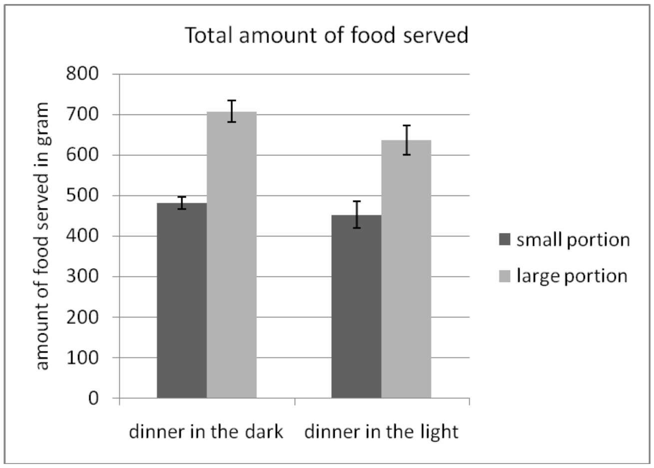

Figure 1: Total amount of food served for the two main courses. Error bars indicate 95% boostrapped confidence intervals.

Dependent and control variables

As a behavioral measure of satiety, we counted the number of fruit sticks that participants took and ate for dessert. In the questionnaire, we asked participants to estimate the total weight and calories that they had consumed in total for both main dishes. They were also asked to rate their hunger and the degree to which they thought they had overeaten on a scale from 1 (not at all) to 7 (very much). A number of control variables regarding hunger, food preferences, enjoyment, and general attitudes towards eating were also assessed, but none of these variables showed a strong relationship with the amount of food received, consumed, or estimated, so we will not discuss them further.

Participants

The average age of the participants in the experimental condition was 24 years (SD=2.8), and they had a mean body-mass index (BMI) of 22.9 kg/m² (SD = 3.2). Thirty of these 64 participants were female, and 52 were students at local universities. None of them were vegetarian or dieting. Participants in the small portion group and in the large portion group were matched by gender, age, student status, and BMI. The participants in the control condition were similar to those in the experimental condition in terms of age, BMI, and gender distribution.

Results

Actual amount of consumption

The amount of consumption was contingent on the portion size received. In the experimental condition in the dark, participants with small portions on average ate 452g (SD = 62g), which was 94% of the amount served. Those with large portions on average ate 626g (SD = 106g), or 89%. In the control condition in the light, participants with small portions ate 432g (96%; SD = 72g), compared to participants with large portions who eat 525g (83%, SD = 109g) —see Figure 2.

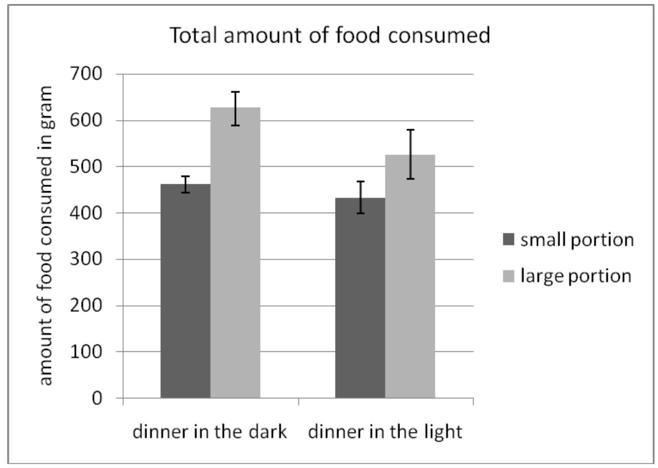

Figure 2: Total amount of food consumed during the two main courses. Error bars indicate 95% boostrapped confidence intervals.

Estimation of food consumed

Participants with small portions in the dark experimental condition slightly overestimated the amount of food they had eaten (M = 496g, SD = 147g) while those with large portions underestimated it (M = 556g, SD = 196g). Thus, even though participants in the large condition actually consumed 39% more food as compared to the small condition, their estimate is only 12% higher. Comparable results were obtained for the estimation of calories. In the light control condition, participants with small portions estimated they had eaten on average 416g (SD = 143g) versus 504g (SD = 121g) for the large portions. Thus, for large portions participants estimated 21% more consumption while they actually ate 18% more.

Measures of satiety

In the dark experimental condition, those with small portions took 8 fruit sticks for dessert (SD = 4.0) while those with large portions took 7 (SD = 3.5), F[59][1] = .82, prep = .74. In the light control condition, this difference was more pronounced: Those with small portions took 12 fruit sticks (SD = 5.4) while those with large portions took only 8 (SD = 3.8), F[24] = 4.3, prep = .092—see Figure 3.

[1] For one participant the exact amount of food served could not be measured, there were a few missing values in the questionnaire, 3 participants vastly overestimated the amount of food they had consumed, and 11 participants did not drop their toothpicks on their own plates, which reduced the number of valid cases in some of the analyses.

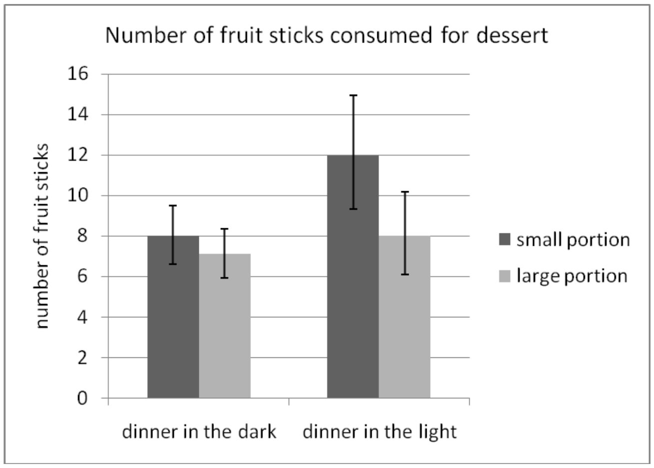

Figure 3: Number of fruit sticks participants served themselves for dessert. Error bars indicate 95% boostrapped confidence intervals

After having eaten the main course dishes and dessert, everyone ended up feeling as though they had eaten roughly the same amount: Self-reported hunger was largely independent of the served portion size and the experimental condition. In the experimental condition, the mean hunger rating for small portions was 1.7 (SD = 1.01), and for large portions 1.5 (SD = 1.02). In the control condition, the ratings were M = 1.6 (SD = 1.22) and M = 1.2 (SD = 0.75) respectively. Feelings of having overeaten followed a similar pattern. Given that participants with small portions in the light had to eat 50% more dessert than those with small portions in the dark to get to the same satiation level, this further supports the idea that visual cues of consumption of the main dishes influenced the amount of satiety felt from eating them: When people ate small portions that they could see, they ate more dessert to make up for it.

Discussion

Large differences between the amount of food served in the dark or in the light led to large differences in the amount of food eaten, confirming past research showing that consumption is contingent on portion size. However, when eating in the dark, where visual cues were not available and only internal cues could be used, participants had difficulties estimating the amount of food they had actually consumed. This difficulty was also reflected on a behavioral level: The amount of dessert (fruit sticks) participants served themselves was largely independent of the food they had previously consumed in the dark (Figure 1). Likewise, participants eating small or large portions in the dark did not end up feeling different amounts of satiety at the end of the experiment.

This is in contrast to the control condition in the light where participants made much more accurate estimations of their consumption, presumably because visual cues were readily available. Furthermore, with the availability of visual cues came greater differences in the amount of food consumed: Even though the actual differences between the large and small portions were reduced compared to the dark condition, participants in the light condition who received large portions still compensated for them to a greater extent by leaving more food on their plates and eating less dessert than those with small portions.

Together, these results indicate that internal physiological signals do not provide particularly accurate feedback regarding food consumption and satiety, and that food consumption and satiety are mainly controlled by cognitive factors that rely on visual cues.

These results support the powerful effects of manipulating visual food cues reported in previous research. Our findings further indicate that the pronounced insensitivity to visceral feedback found for obese people (Schachter, 1968; Stice, Spoor, Bohon, & Small, 2008) may not be the only driver of overeating. The (visual) environment also exerts an important influence that should not be underestimated: Tesla was right to avoid eating portions that cannot be visually estimated.

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